ARMY RESEARCH LABORATORY

Free-Flying Magnetometer Launcher Conceptual Design

John A. Condon
Michael S.L. Hollis
Fred J. Brandon

ARL-MR-353 MAY 1997

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Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5066

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Abstract

The need exists for a launch mechanism to propel a magnetometer (i.e., free-flying magnetometer [FFM]) from a high altitude sounding rocket or low earth-orbiting (LEO) satellite. Research has been conducted to conceptually design a unique launcher for this purpose. This launcher will provide the greatest degree of variability in FFM launch velocity and spin rate, according to the given requirements, and will allow for two distinct FFM spatial geometric launching orientations with respect to the major launch axis. Also, this launcher will be relatively easily integrated into existing or future space or rocket host vehicles.

ACKNOWLEDGMENTS

The authors would like to acknowledge David Hepner of the Weapons Concepts Division, Weapons and Materials Research Directorate, U.S. Army Research Laboratory, for his aid in acquiring video during prototype launcher testing.

The authors would also like to acknowledge Charles Mitchell of Dynamic Sciences, Incorporated, for his advice and spare parts donations during the fabrication of the prototype launcher.

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FREE-FLYING MAGNETOMETER LAUNCHER CONCEPTUAL DESIGN

1. INTRODUCTION

The customer, Jet Propulsion Laboratory, Pasadena, California, (Javadi, 1996) requested the U.S. Army Research Laboratory (ARL) to assist in providing a conceptual design study of alternate means of launching magnetometer devices from high altitude sounding rocket and low earth-orbiting (LEO) satellite host vehicles, which would, in turn, measure characteristics of the magnetic fields of the earth's north and south poles. This design study included an initial trade-off study and market research study to select the most feasible launch concepts, including those currently being considered by others, and to select a promising candidate for further study and analysis (see Table 1). The chosen candidate would then be designed and/or tailored to meet the specific requirements of the free-flying magnetometer (FFM) launching mission. From this design study, ARL chose the concept entitled "ARL Drive Wheel Launcher" in Table 1. Some of the competing concepts are shown in Appendices A through C.

The chosen candidate employed existing technology developed for recreational sporting purposes, specifically in the baseball batting and hockey goalie training fields, whereby baseballs and hockey pucks are launched at the respective hitter or goaltender user (Boni 1996). This launcher concept was believed to be the most cost efficient and required the least amount of development time. This technology was modified to launch the hockey puck-shaped FFM projectile in two different configurations, both supplying variable user-specified spin rates, and linear launch velocities. The first configuration launches the FFM in the frontal (i.e., "face on") orientation as depicted in Figure 1. The second configuration launches the FFM in the sideways (i.e., "edge on") orientation as depicted in Figure 2. Both of these figures include conceptualized renderings of the FFMs being launched from their host vehicle.

This report documents the conceptual launcher design, including prototype fabrication and testing.

2. DRIVE WHEEL LAUNCHER HARDWARE DESIGN

The ARL launcher system is designed to employ two independent brushless DC motors, which will rotate two friction type drive wheels and will contact the FFM and impart both spin and linear launching forces (an optional design could use one motor and a specialized drivetrain to drive both wheels). Each wheel and connected motor has a variable pitch control that varies the

Table 1. FFM Launcher Trade-Off Study
(a score of 10 is best)

Factor	Wt.	Rotating Table (include early ARL concepts & others)		Tube/Gun Launch (spring, gas, and explosive deployment, means, incl. early ARL concepts & othrs)		ARL Drive Wheel Launcher		OPAL Stanford U. Launcher	
		Score	Wt x Score	Score	Wt x Score	Score	Wt x Score	Score	Wt x Score
Space usage	5	8	40	5	25	6	30	6	3C
Launcher weight	6	7	42	7	42	7	42	7	42
Min. effect of FFM launching on host vehicle dynamics	7	5	35	4	28	6	42	6	42
Min. loadings on launcher created by dynamics of host vehicle	4	4	16	5	20	6	24	3	12
FFM launchers' ability to provide variable edge-on/face-on launch, adjustable before mission	10	4	40	4	40	7	70	3	30
Independency of FFM spin and linear launch velocity	10	5	50	4	40	7	70	5	50
Independence of launcher with respect to host vehicle's orientation and dynamics at time of FFM launch	8	3	24	6	48	6	48	6	48
Development of basic launch technology	6	3	18	7	42	8	48	9	54
Multi-launch capability	7	3	21	3	21	3	21	4	28
Storage and re-load capability	8	8	64	3	24	9	72	7	56
FFM launch reliability	9	6	54	5	45	7	63	7	63
FFM launch accuracy and repeatability	10	8	80	6	60	8	80	8	80
Low moving part count	5	5	25	6	30	7	35	4	20
Integration capa-bility into present and future satellite platforms	7	5	35	4	28	5	35	5	35
Off-the-shelf usage of parts	4	3	12	4	16	5	20	5	20
Power usage	10	3	30	5	50	4	40	4	40
Total Score		**80**	**586**	**78**	**559**	**101**	**740**	**89**	**650**

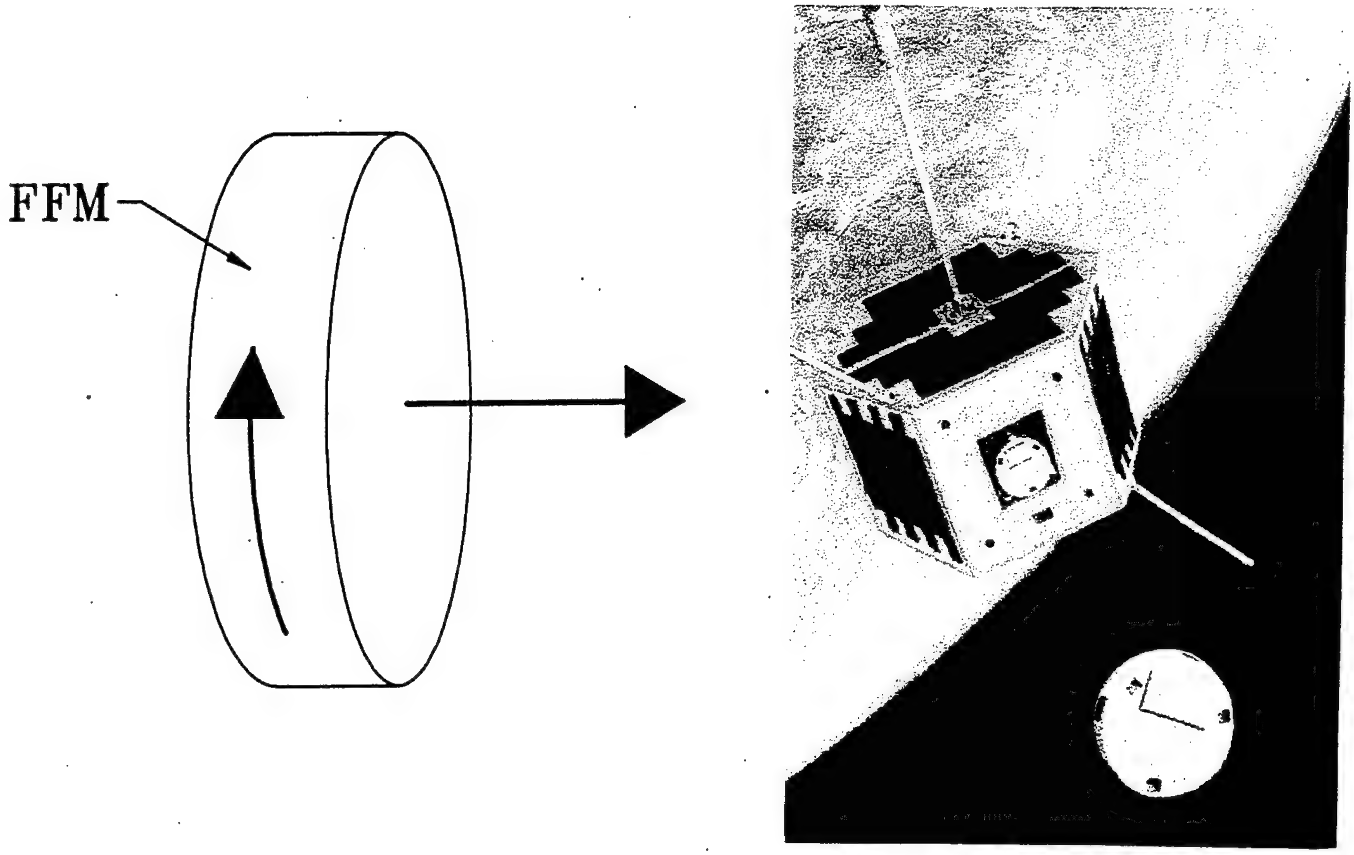


Figure 1. FFM Frontal Launch Orientation (ref: Stanford University web pages).

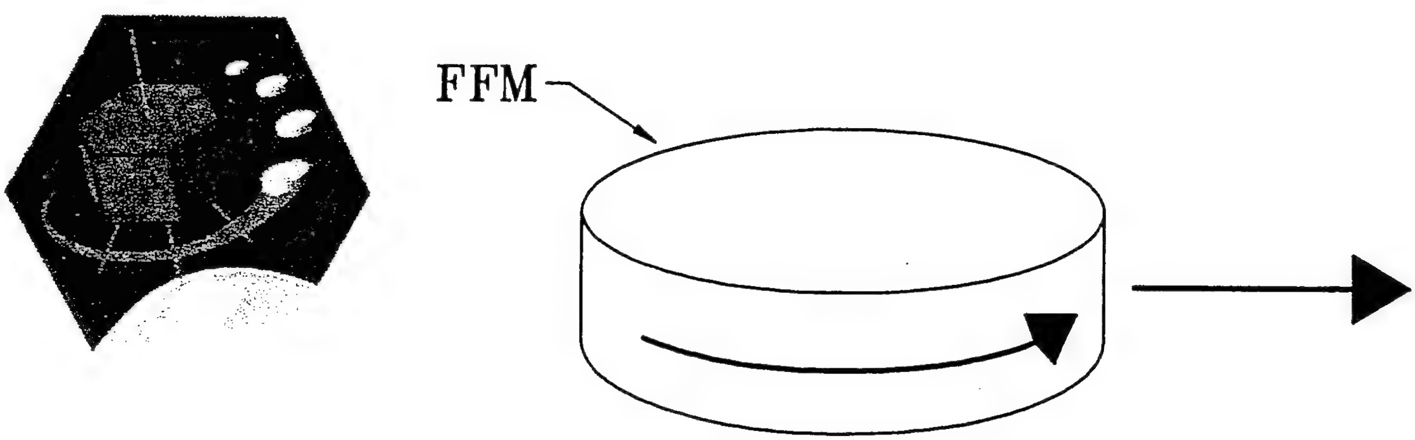
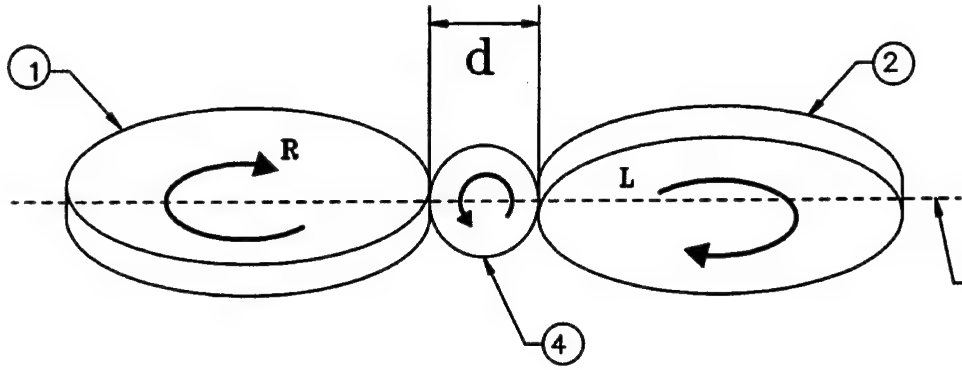
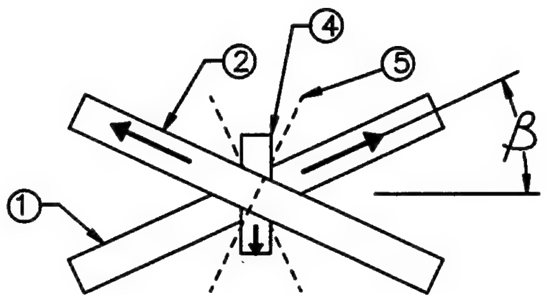


Figure 2. FFM Sideways Launch Orientation (ref: Stanford University web pages).

orientation of the drive wheels with respect to the FFM. The spinning of the wheels will, in turn, draw an FFM into and through a gap between the two drive wheels. The FFM's spin rate, linear release velocity, and launch orientation (i.e., sideways or frontal) will be controlled by the speed, direction of rotation, and orientation of the drive wheels with respect to the FFM's orientation. The drive wheels will be driven through either direct drive or gear head (i.e., speed reduction) means. Note that brushless, independent motors were used for high efficiency and low loss characteristics and are well suited for a space environment. Also note that the motor and its torque versus revolutions per minute (rpm) performance was chosen, partly based on an assumed allowable time to reload and launch another FFM. This assumed time increment was relatively short and conservative. Therefore, if larger time increments were more representative of the actual FFM launch scenario, a motor(s) with lower torque capabilities could be used. Lower torque motors would be allowed to rotate (i.e., "spin up") to the required respective speed before FFM contact and launch.

In the frontal configuration, as shown in Figure 3, drive wheels (1) and (2) are spinning in opposite directions and are tilted about a common axis (3) which runs through the centers of the FFM (4) and drive wheels. The axes of the drive wheels (5) are tilted in equal yet opposite directions. The arrows in Figure 3 indicate the direction of spin and the direction in which the FFM will launch. Figure 4 displays a vector representation of the applied forces to the FFM attributable to the wheels. The drive wheels are spaced apart so that their adjacent peripheries are separated by a distance (d, shown in Figure 3, front view) equal to or slightly less than the diameter of the FFM. (Note, this distance, or gap, was adjusted during the prototype testing to provide satisfactory FFM launch velocity and spin.) Altering the tilt angle (ß, shown in Figure 3, side view) and the spin rate of the wheels will provide a broad range of linear velocities and spin rates. The spin rate provides gyroscopic stability of the FFM while it is in flight. A spreadsheet drive wheel sizing study and launcher performance analysis for the direct drive, frontal launch configuration was performed to verify basic FFM dynamics. Data from this spreadsheet analysis, including predicted performance data and curves for two drive wheel sizes, are shown in Appendix D. This appendix information describes the methodology that was used in sizing the launcher drive wheels, based on maximum FFM velocity and spin rate. The appendix also depicts two drive wheel size scenarios with a random selection of required FFM launch velocity and spin rates.





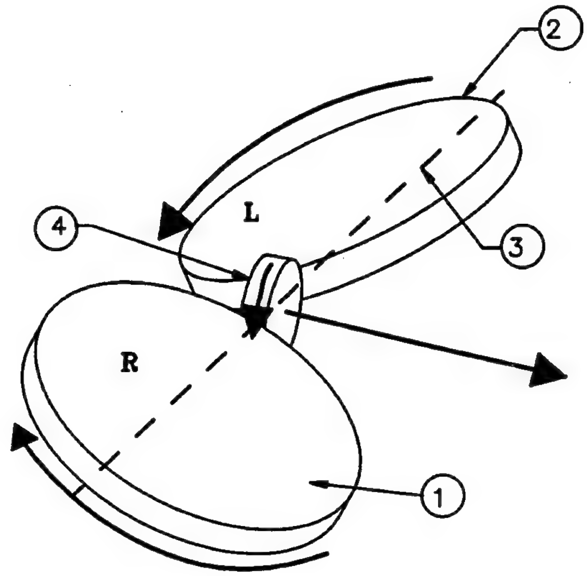


Figure 3. Frontal Configuration.

The sideways launch configuration will use the same wheels, except the tilt angle will be nonexistent and both wheels will spin in the same direction. Figure 5 displays wheels (-1-) and (-2-) spinning in the same direction, about parallel axes. The FFM will be held in place by a low friction gate (-6-) until the FFM achieves the desired spin rate. In this configuration, the spinning FFM's linear launch velocity will be initiated by the controlled braking of drive wheel (-2-). A range of launch velocities can be achieved by changing the braking, i.e., reducing the spin rate of wheel (-2-). Small variations in this design scheme can be made to further optimize this sideways launch configuration.

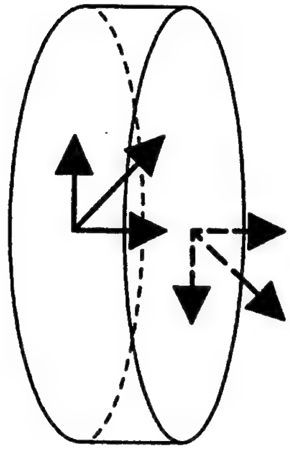


Figure 4. Frontal Configuration, Force Vector Representation.

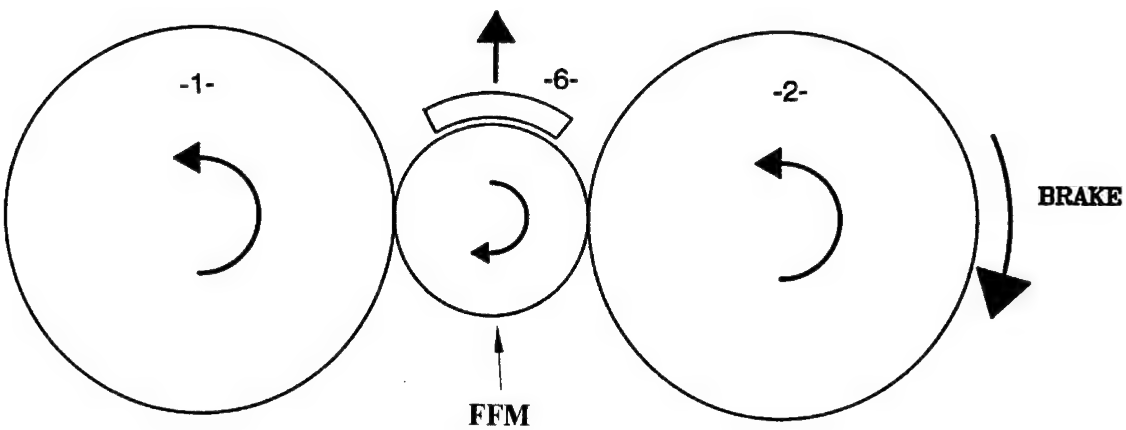


Figure 5. Sideways Configuration, Front View.

An assembly drawing for the launcher is shown in Figure 6. An aluminum canister provides both storage and mechanical guidance of the FFMs until launch. An indexing system is incorporated into the canister to provide advancement, holding and releasing capabilities for both the FFM being launched and the FFMs in storage. In both the frontal and sideways launch configurations, a braking system imparts resisting frictional forces to the edges of the FFM as it is being advanced by the canister's feed spring. The next-to-be-launched FFM will be held in place by these spring-actuated brake pads until an electrically energized "release" solenoid overcomes the forces generated by the compression springs. An optical proximity sensor will detect passage of the launched FFM and will signal the actuation of the release solenoid. Mechanical gating, using

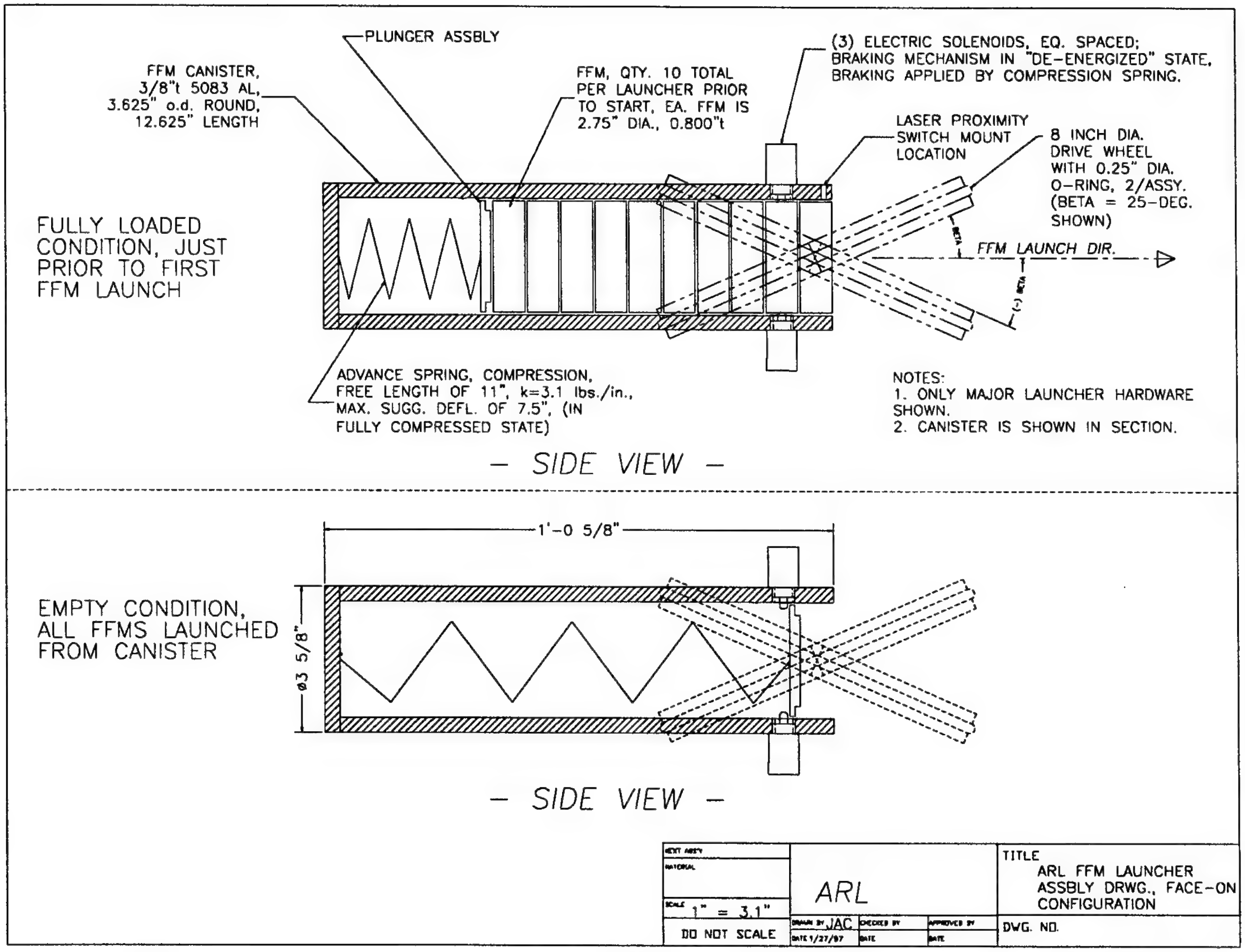


Figure 6. Assembly Drawing for Frontal Configuration.

low friction wheels and/or materials, is employed in the sideways launch configuration to allow the FFM to be held and rotated to the required rpm rate before it is released. The gating is designed to resist any forward linear forces generated by the drive wheels until release and also provide the least amount of disturbance of the FFM's spinning about its geometric axis (i.e., "tip-off"). Working Model 2D dynamic/kinematic simulation software from Knowledge Revolution was used as an aid in designing the indexing system for the full-scale launcher. By iteratively choosing various spring and damper combinations, as well as timed simulated solenoid retraction forces, a functional indexing system was developed. Figure 7 shows the Working Model 2D simplified advancement, holding and releasing mechanisms in the frontal launcher design.

To minimize the detrimental reaction forces imparted to the host space vehicle during FFM launch and to rotationally balance a "spinning" host space vehicle, two launchers could be oppositely oriented to one another in the host vehicle. Depending on the total required number of FFMs to be launched simultaneously, two more oppositely oriented launchers could be added at a 90° orientation to the first two. This would provide for four simultaneous FFM launches. Each launcher is designed to hold nine FFMs in storage.

It is envisioned that the launcher will be arranged within a closed loop feedback control system to initiate and stop the FFM launch phase of the mission as well as translate the most accurate flight dynamics to the FFM projectile. A simple schematic block diagram of the launcher system is shown in Figure 8. No details of the control system have been developed in this work but attention has been given to the interfacing issues required in such a system.

The main components and characteristics of the launcher system (using only one launcher) are listed in Figure 9.

3. LAUNCHER DESIGN REQUIREMENTS

The design requirements, as directed by the customer, are outlined in Figures 10 and 11.

4. SCALED DRIVE WHEEL LAUNCHER PROTOTYPE FABRICATION

An operational 1/3 scale prototype of the ARL FFM launcher for the frontal launch configuration is shown in Figures 12 and 13. This prototype was built to provide proof-of-principle testing, form/fit verification, and aid in the overall conceptual design effort. This prototype launcher does not include the indexing hardware. The specifications for the primary

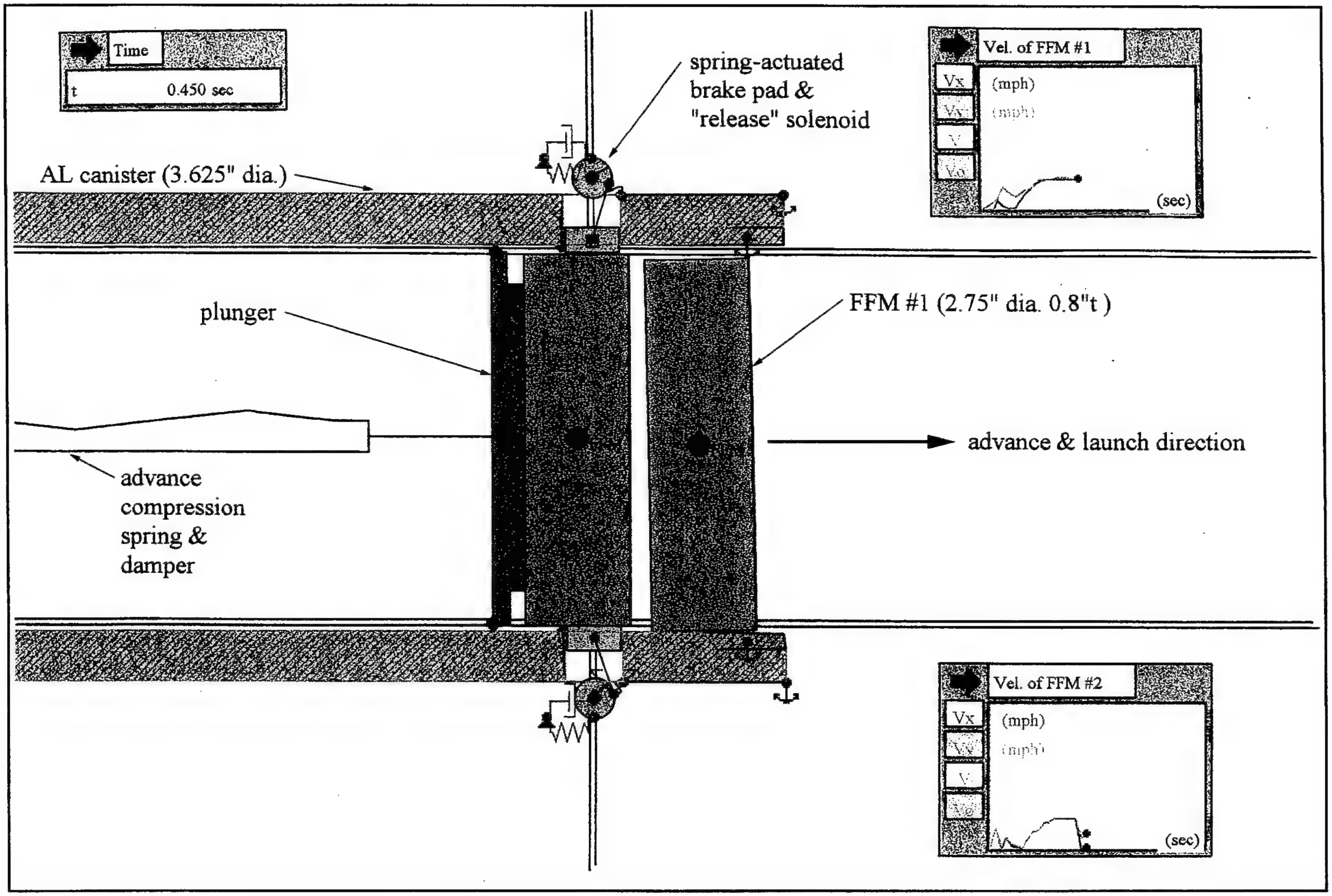


Figure 7. Kinematic Simulation Software Output.

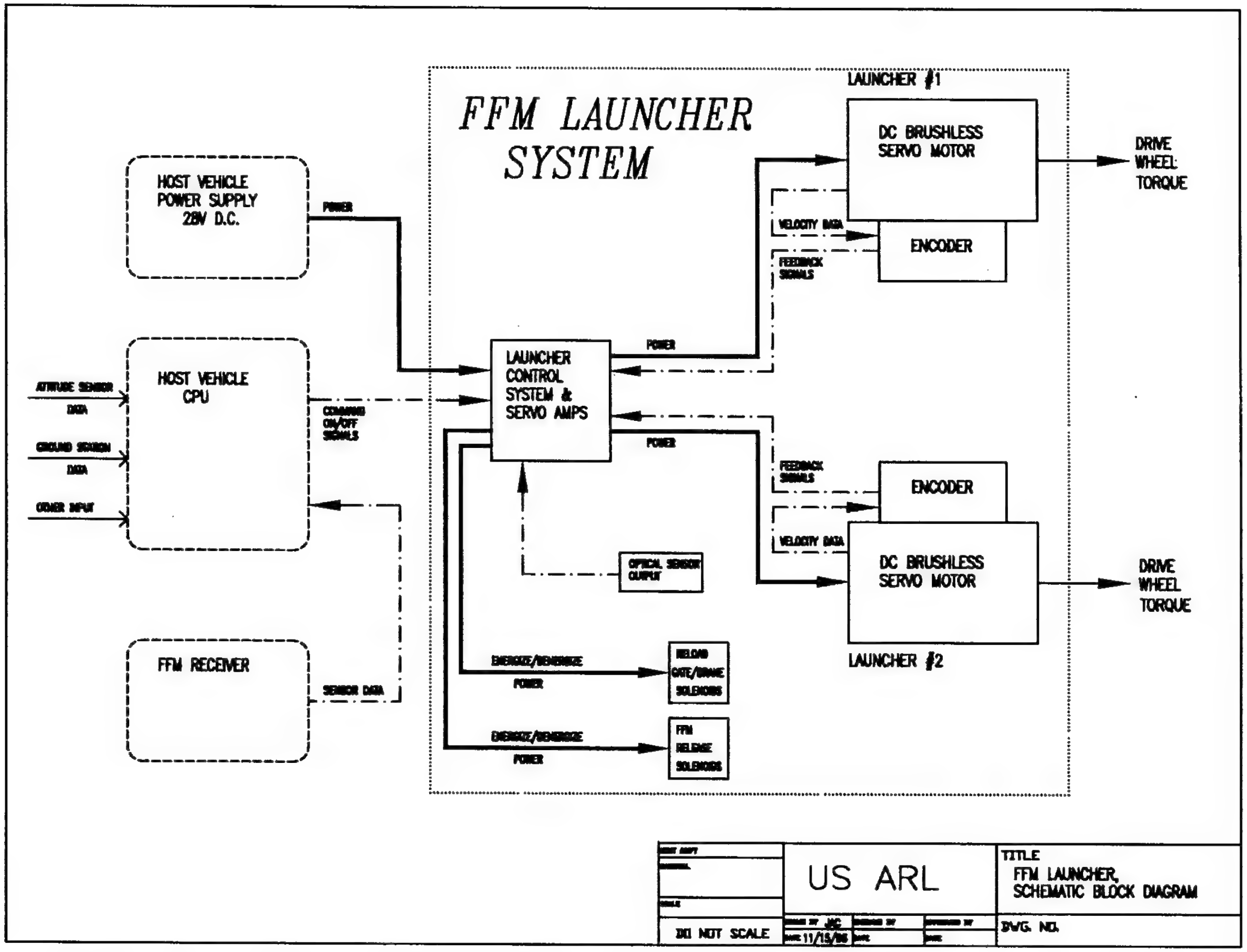


Figure 8. Schematic Block Diagram of Launcher System.

hardware used in the scaled launcher are listed in Figure 14. The reason for prototyping the frontal launch configuration as opposed to the sideways configuration was because the authors believed that frontal was more difficult to design and because no specific hardware or application existed.

* 2 brushless DC motors (peak output torque rating of ~250 oz-in. each) per launcher with speed sensor rings, amplifiers, and feedback control.
* power and command-data system interfaces for host vehicle.
* FFM storage canister and springs/solenoids for indexing mechanisms.
* optical proximity switches, solenoids, wiring, and circuitry.
* miscellaneous support base and structure and related assembly hardware.
* launcher weight = 20 to 30 lb.
* launcher space usage = 2 to 3 ft^3.

Figure 9. Estimated Full-Scale Launcher Information.

1. **Host launch vehicle platform**; FFM launcher should be designed to operate aboard a low earth-orbiting satellite at prescribed sun synchronous altitude; integration issues should be considered important (Pegastar/Pegasus satellite typical).
2. **Launch (host) vehicle on-board power supply and allowable FFM launcher power usage**; 28 V DC with wattage requirement governed by host power system, 212 W-hr/orbit, typical. Stand-alone power systems integral to FFM launcher are not feasible.
3. **Computer control system usage**; any FFM launcher design would require a control system, either provided by host satellite system or provided with launcher as a stand-alone system.
4. **Use of host vehicle pressurized gas supply**; nitrogen is good candidate; gas could also be stored in stand-alone canister(s) with launcher to provide accessory power.
5. **Packaging requirements of FFM launcher**; FFM launcher should be designed to be modular in nature to optimize interchange ability with various host launch vehicles. Thermal and electromagnetic interference/electromagnetic radiation (EMI/EMR) shielding should be considered in the FFM launcher design. Weight and space parameters of FFM launcher should be minimized to ensure compatibility with all possible satellite platforms.
6. **Dynamics of launch (host) vehicle**; i.e., velocities and accelerations from vehicle launch through FFM launch phases should not hinder operations of the FFM launcher. Capability should exist to interface with host vehicle to provide required stabilization and pointing to ensure proper FFM launch direction. Also, reaction impulses and/or momentum transfer from FFM launches should minimally affect host vehicle dynamics.
7. **Desired orientation of FFM to be launched**; i.e., face on or edge on, design should allow for both, determined before ground launch of host vehicle for each mission.
8. **FFM launcher should provide independent parameters of FFM spin axis and rate, and linear velocity** which would be "dialed in"/selected before ground launch of host vehicle for each mission.
9. **Multi-launch capability of FFM launcher**; 2 to 4 FFMs launching simultaneously, approximately 100 units stored. Reload time for subsequent launch dependent on launcher design.
10. **FFM weight, geometry, and material composition**; $\leq$ 100 grams, right circular cylinder, 4 to 7 cm diameter x 1 to 2 cm height, exterior of graphite composite or other lightweight material of equal strength and hardness.

Figure 10. Critical Configurational Requirements.

1. FFM spin rate = 600 to 1200 rpm (1% deviation)
2. FFM maximum tip-off angle = 1°.
3. FFM launch velocity = 1 to 10 m/s.

Figure 11. Required Operational Parameters.

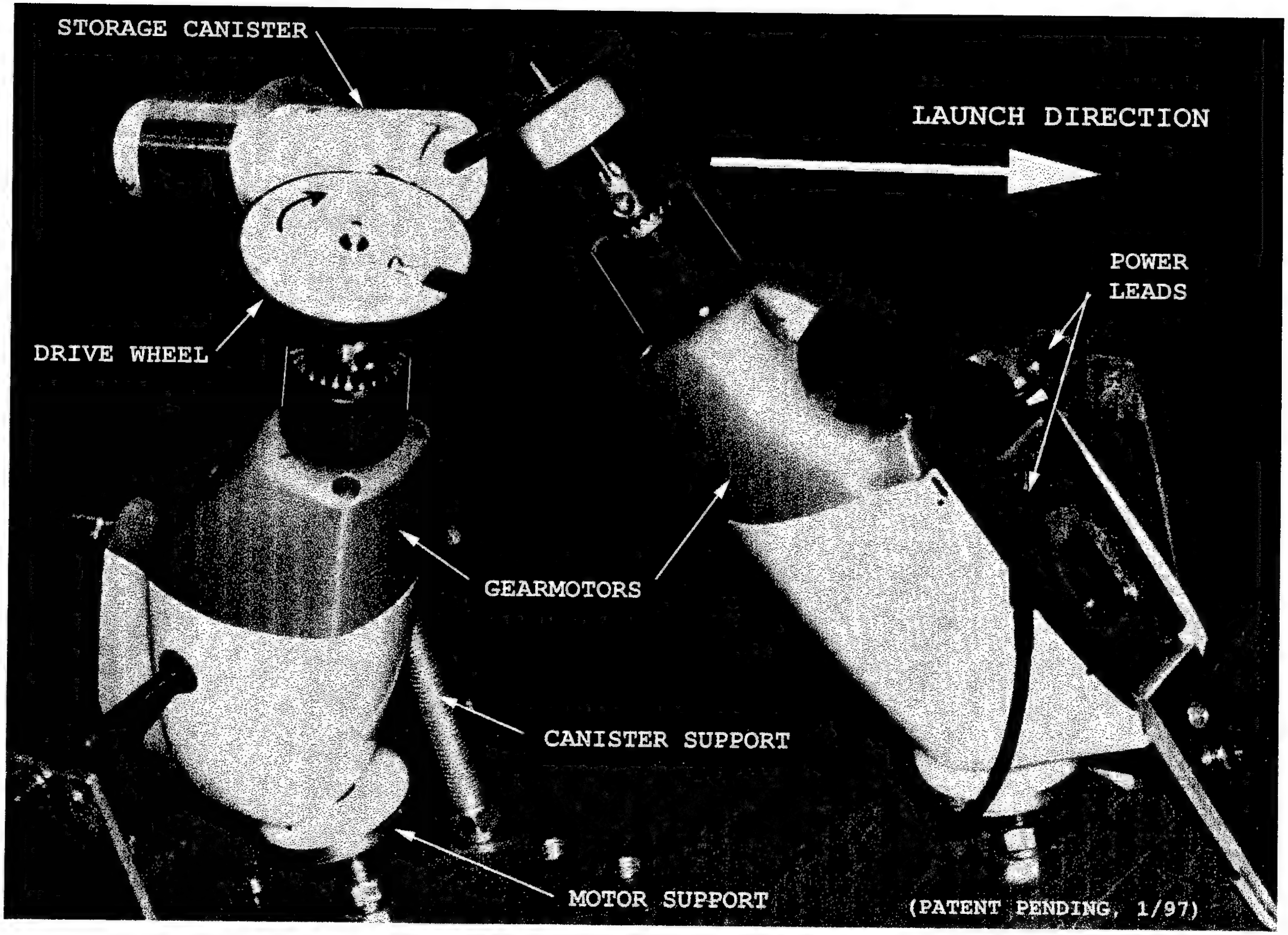


Figure 12. Side View Photograph of 1/3 Scale Prototype Launcher.

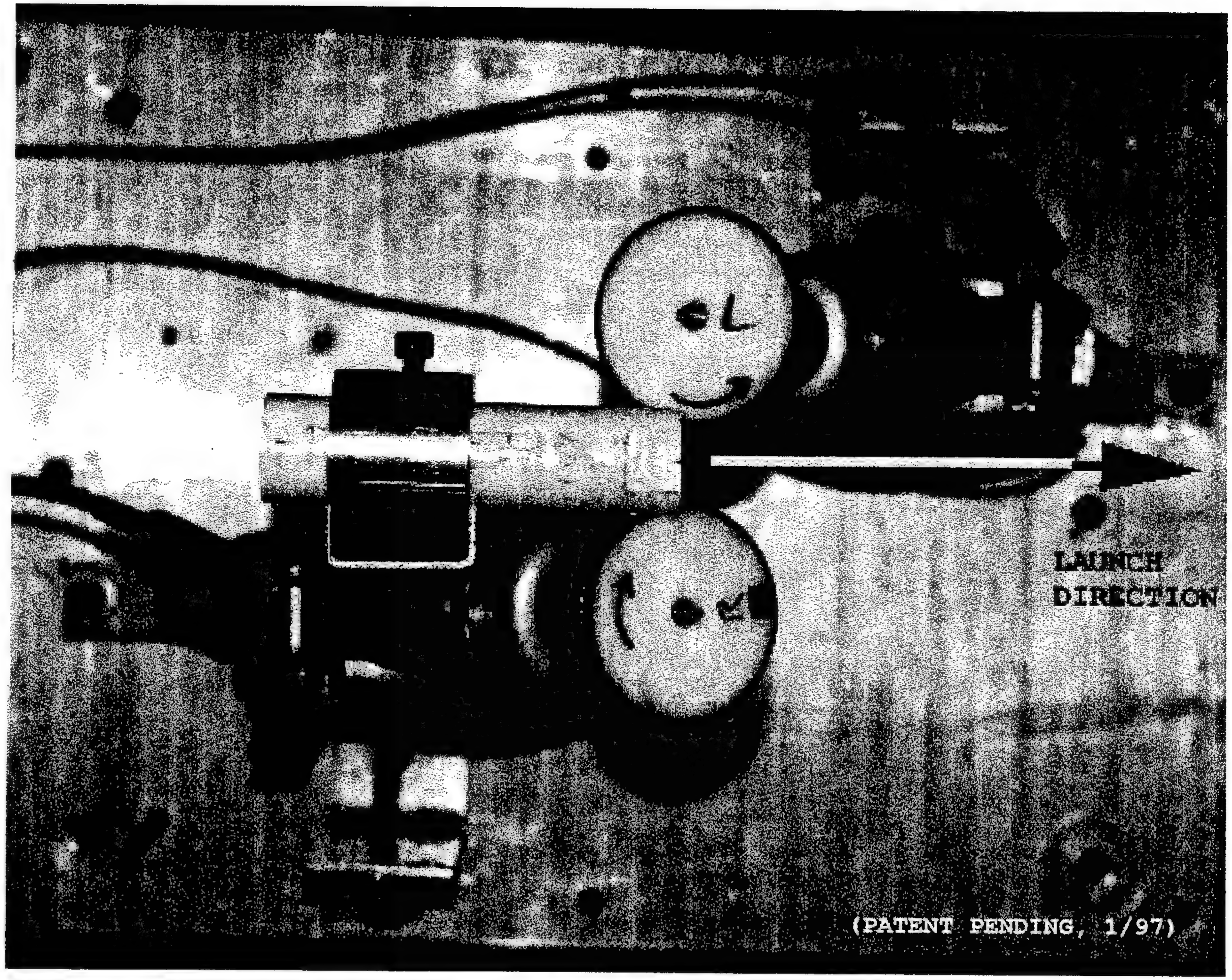


Figure 13. Top View Photograph of 1/3 Scale Prototype Launcher.

(2) DC motors with gear heads; maximum output equals 750 rpm (at no load condition, drawing 2.5 to 3.8 amperes); average output torque at 10-ampere draw equals 60 oz-in. as specified by manufacturer.

(2) friction drive wheels (acetal hub material), 2-inch outside diameter with 0.100-inch diameter rubber O-rings (maximum wheel diameter with O-ring installed equals 2.135 inches); 25° orientation from horizontal with FFM at 90° orientation from horizontal.

(1) storage canister, 3/4-inch SCH-40 polyvinyl chloride tubing, 4 inches long, 0.810-inch inside diameter, 1.050-inch outside diameter.

(1) FFM advance helical compression spring (stock item) and plunger assembly, spring constant equals 9.2 oz/in., 0.563-inch outside diameter of coil, 0.032-inch wire diameter.

(1) FFM, 0.800-inch diameter, 0.262-inch thickness, 2.5-gram mass, nylon.

(1) manually variable filtered DC power supply, output 0 to 55 volts DC, 10 amperes DC maximum continuous. (Note, each wheel was independently driven by its own gear motor, but both motors were driven by the same power supply.)

Figure 14. 1/3 Scale Launcher Components.

Performance data from this launcher (drive wheel tilt angle, ß=25°) are shown in Table 2. In each trial, power was first supplied to both drive motors which were free to rotate to a desired spin rate (rpm) corresponding to a specific line voltage and amperage. Upon stabilization of the amperage, an FFM was slowly advanced by hand into the gap between the two drive wheels. Launch velocity and spin rate of the FFM were determined by high speed video. Black markings on the drive wheels and FFM provided visual indications of rotation upon frame-by-frame video playback. Five consecutive still frames of video, taken from the frontal perspective (at 30 frames/second) in front of the launcher, are shown in Figure 15. These video frames are representative of Table 2, Trial No. 2 data.

5. CONCLUSIONS AND RECOMMENDATIONS

Conceptual design, scaled prototype fabrication, and successful proof-of-principle testing were completed for an FFM launcher for the frontal launch configuration. Performance for this scaled launcher was within the range of the required operational parameters given by the customer.

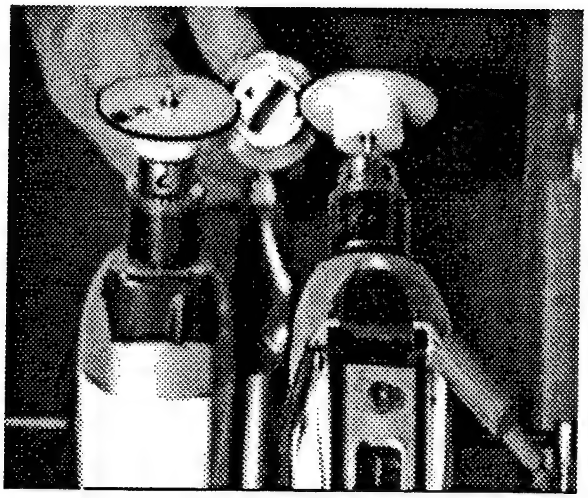
Table 2. 1/3 Scale Launcher Test Data (ß=25°, counter-clockwise FFM spin)

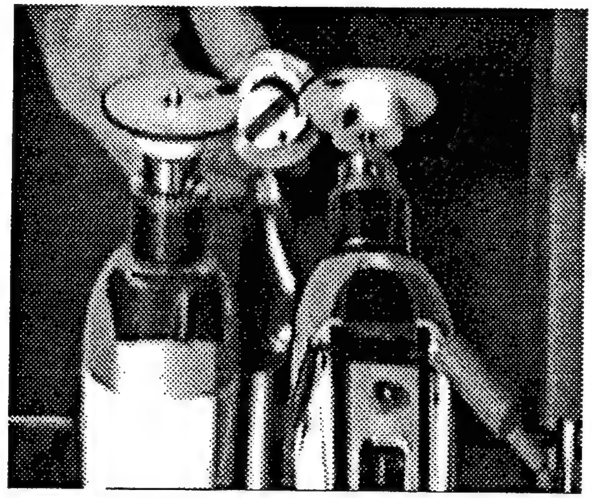
Trial No.	Voltage to drive both motors (volts DC)	Amperage draw from both motors (amps DC)	Interference value between drive wheels and FFM, (d) minus FFM diameter (inches)	Drive wheel spin rate at launch as determined by video[1] (rpm, Hz)	FFM spin rate at launch as determined by video taken from in front of launcher[2] (rpm, Hz)	FFM linear horizontal launch velocity as determined by side-on video (ft/sec, m/s)
1	3	4.4	0.020 - 0.030	550, 9.2	651, 10.9	7.5, 2.3
2	5	4.6	0.020 - 0.030	1014, 16.9	1126, 18.7	8.8, 2.7
3	10	5	0.020 - 0.030	NA[3]	NA	13.5, 4.1
4	15	6	0.020 - 0.030	NA	NA	16.4, 5

[1]Gear motor specification stated 750 rpm @ 4.8 V DC
[2]Rotation estimated from second and third frames after FFM/drive wheel contact.
[3]NA means video sampling rate too slow to estimate FFM spin.

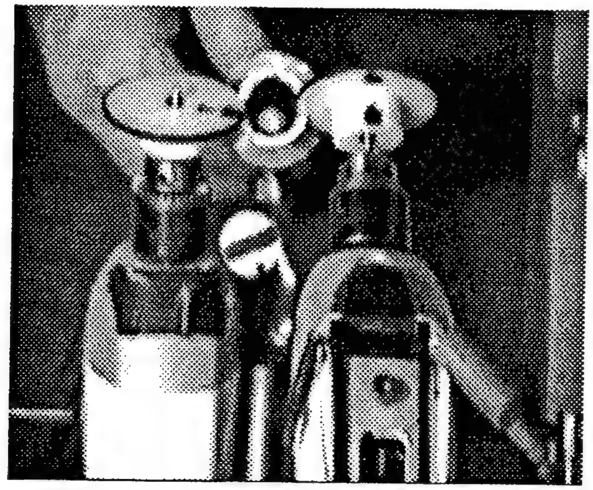
Full-scale prototyping and testing would be the next logical effort to pursue if this work continues. Details of integrating and interfacing with the host vehicle, the electronics and control system design, and the launcher's indexing system would need to be further developed and tested.

Any future testing should include the use of more accurate methods in acquiring FFM linear launch velocity as opposed to the video techniques used herein. For instance, optical measurement sensors positioned within a few inches of the drive wheel/FFM contact location could be employed in this testing. However, video techniques could be used again in future testing to determine FFM spin rate (as was used in this report's efforts) but at a higher sampling rate than the standard 30 frames/second to avoid misinterpreting the video imaging.


Frame @ t=0.0s


Frame @ t=.033s


Frame @ t=.067s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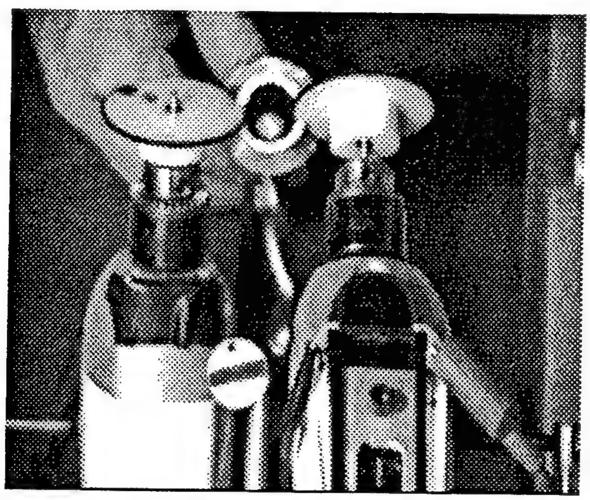
Frame @ t=.133s

Figure 15. Video Frames Taken During Test.

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Javadi, H., Private communication about customer design requirements, Jet Propulsion Laboratory, Spacecraft Telecommunications, 4800 Oak Grove Drive, Pasadena, CA, October-December 1996.

Boni, B., Private discussion about existing technology, Boni Goalie Trainers Inc., 558 Scarlett Road, Weston, Ontario M9P 2S2 Canada, December 1996.

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APPENDIX A

COMPETING CONCEPTS, ROTATING TABLE TYPE

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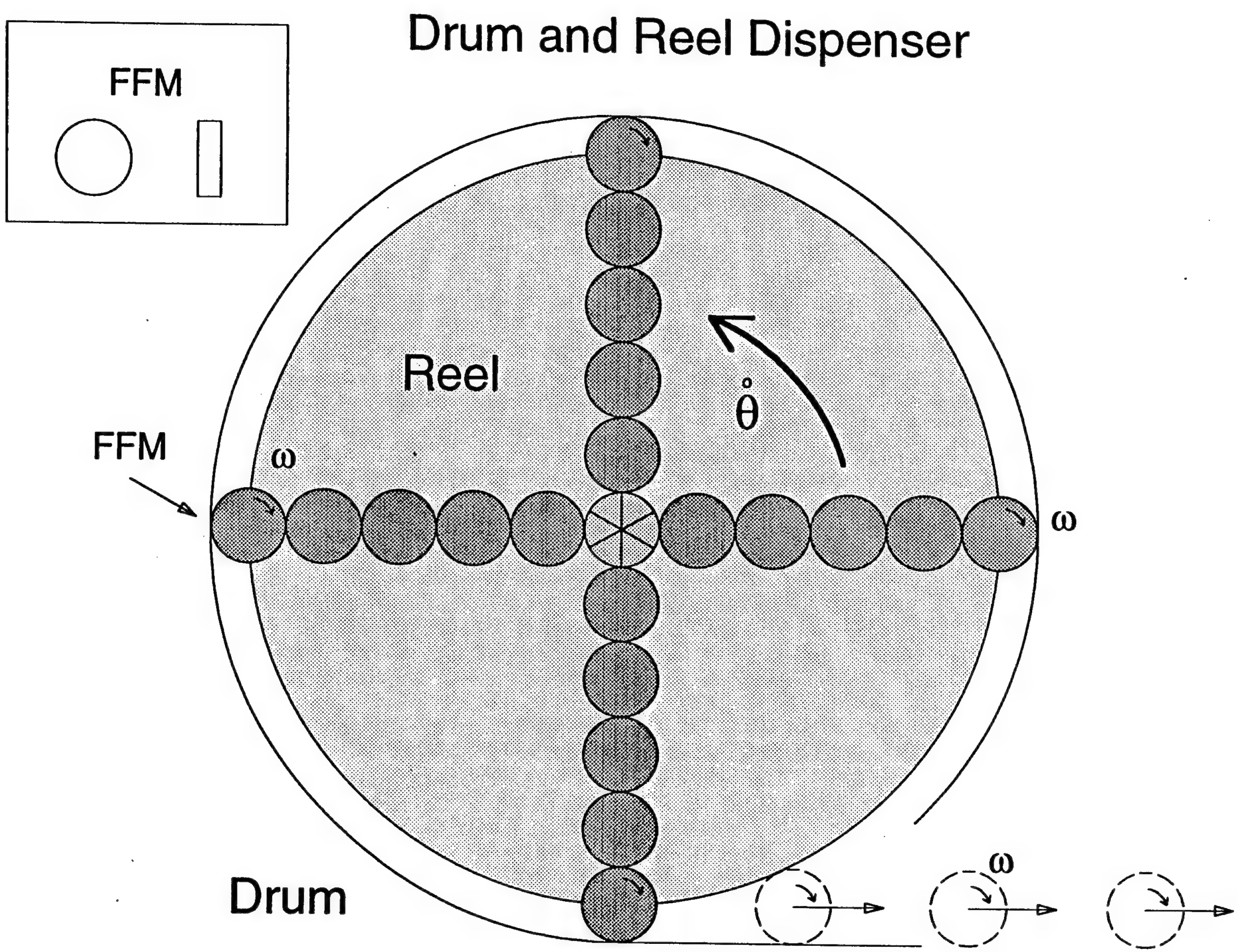

Figure A-1. Rotating Table Launcher Concept #1

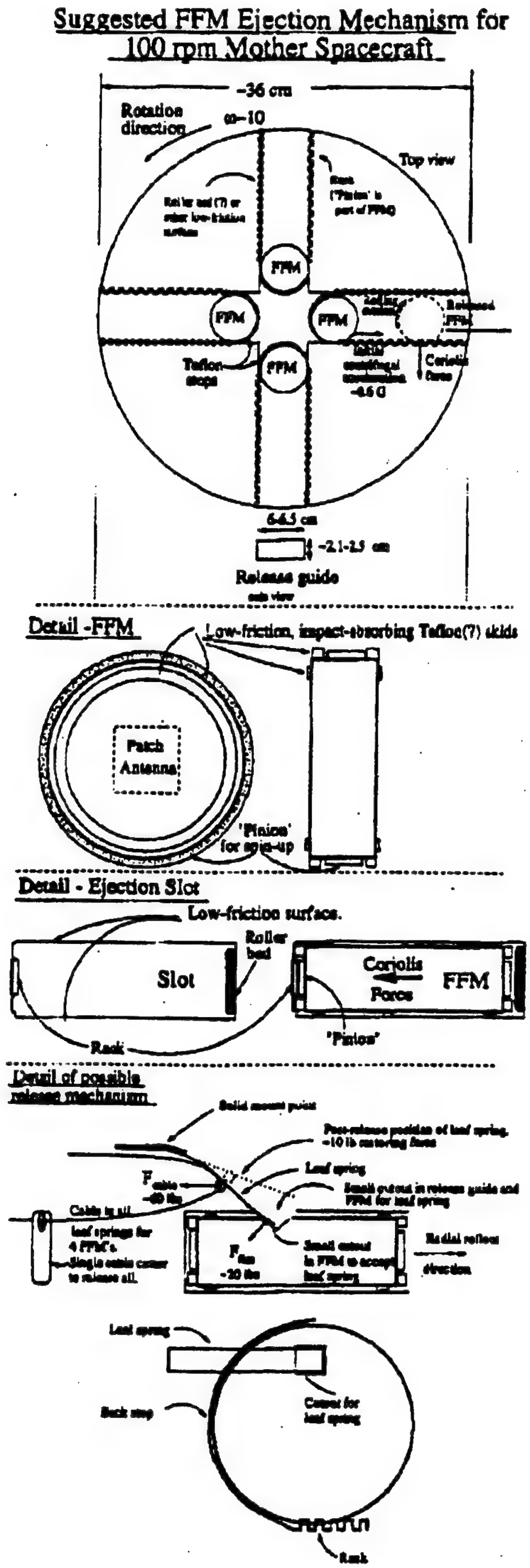

Figure A-2. Rotating Table Launcher Concept #2

APPENDIX B

COMPETING CONCEPTS, GUN/TUBE TYPE

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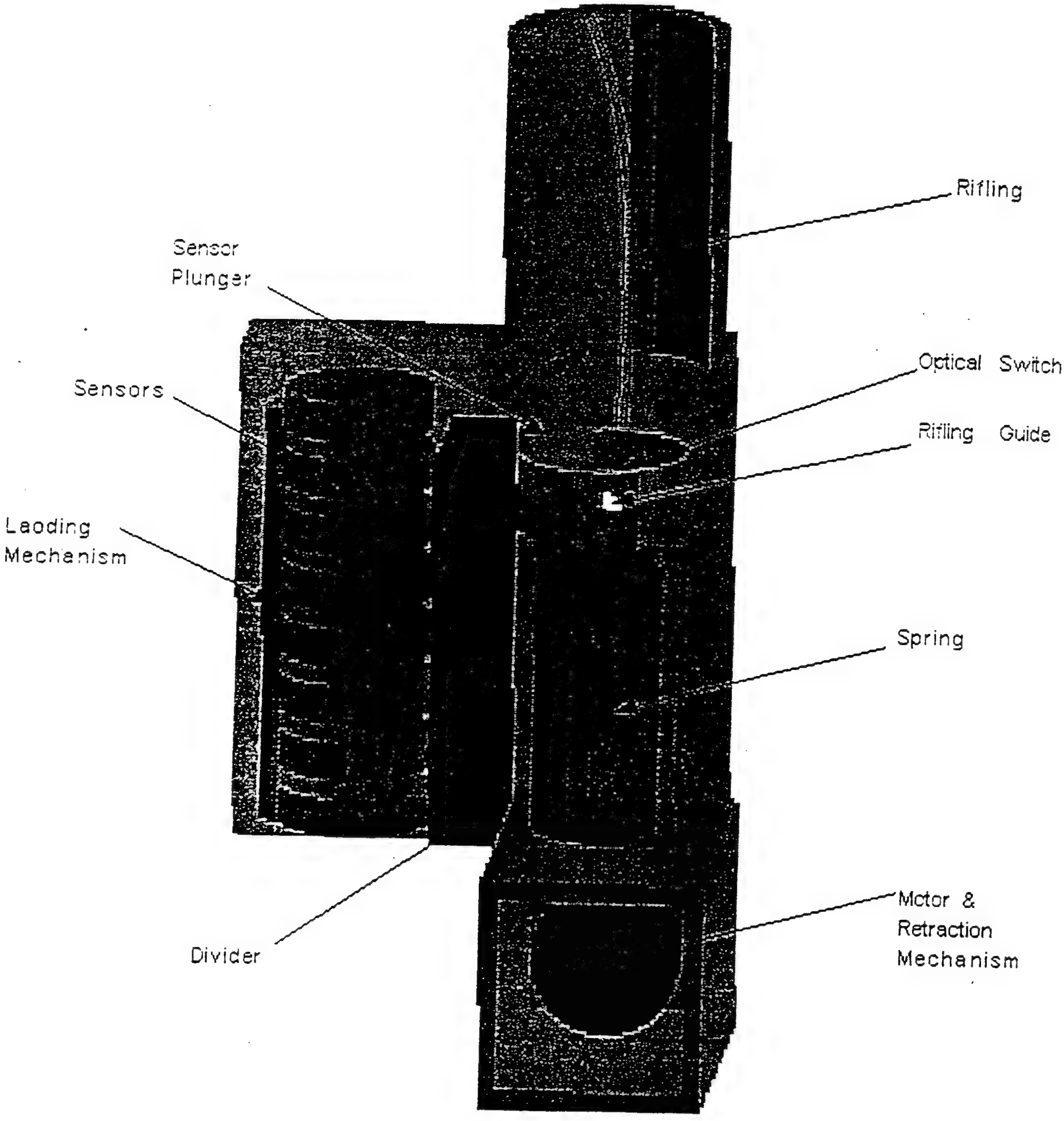
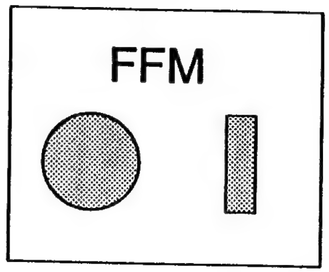


Assembly is ready to fire. (Cocked State)

Figure B-1. Gun/Tube Launcher Concept #1

Gun / Sabot Concepts



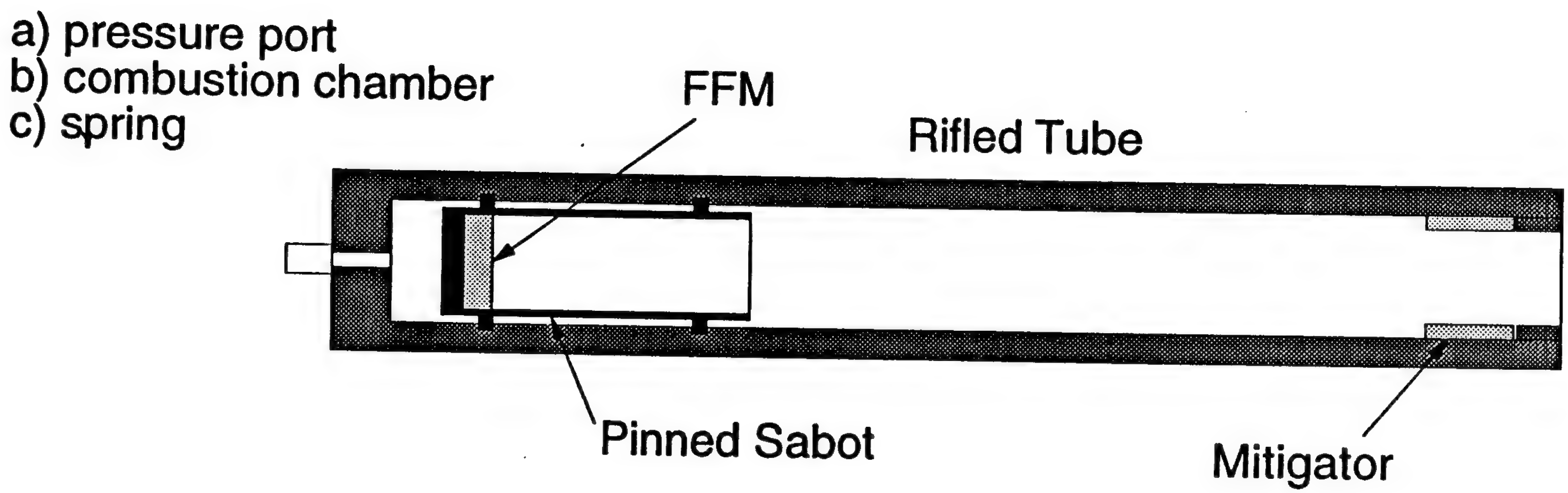
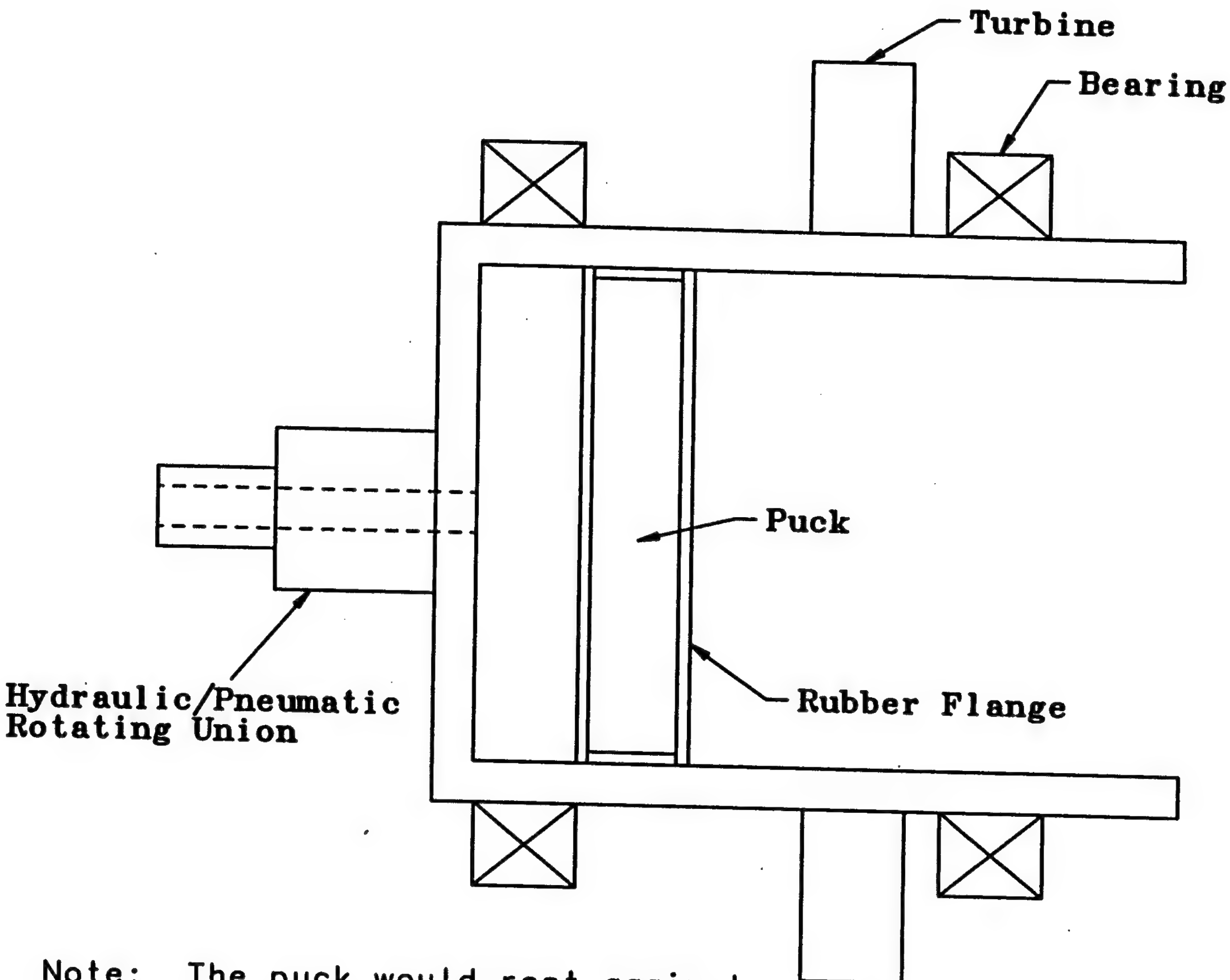


Figure B-2. Gun/Tube Launcher Concept #2



Note: The puck would rest against the back end of the barrel.

Figure B-3. Gun/Tube Launcher Concept #3

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APPENDIX C

COMPETING CONCEPTS, STANFORD UNIVERSITY LAUNCHER

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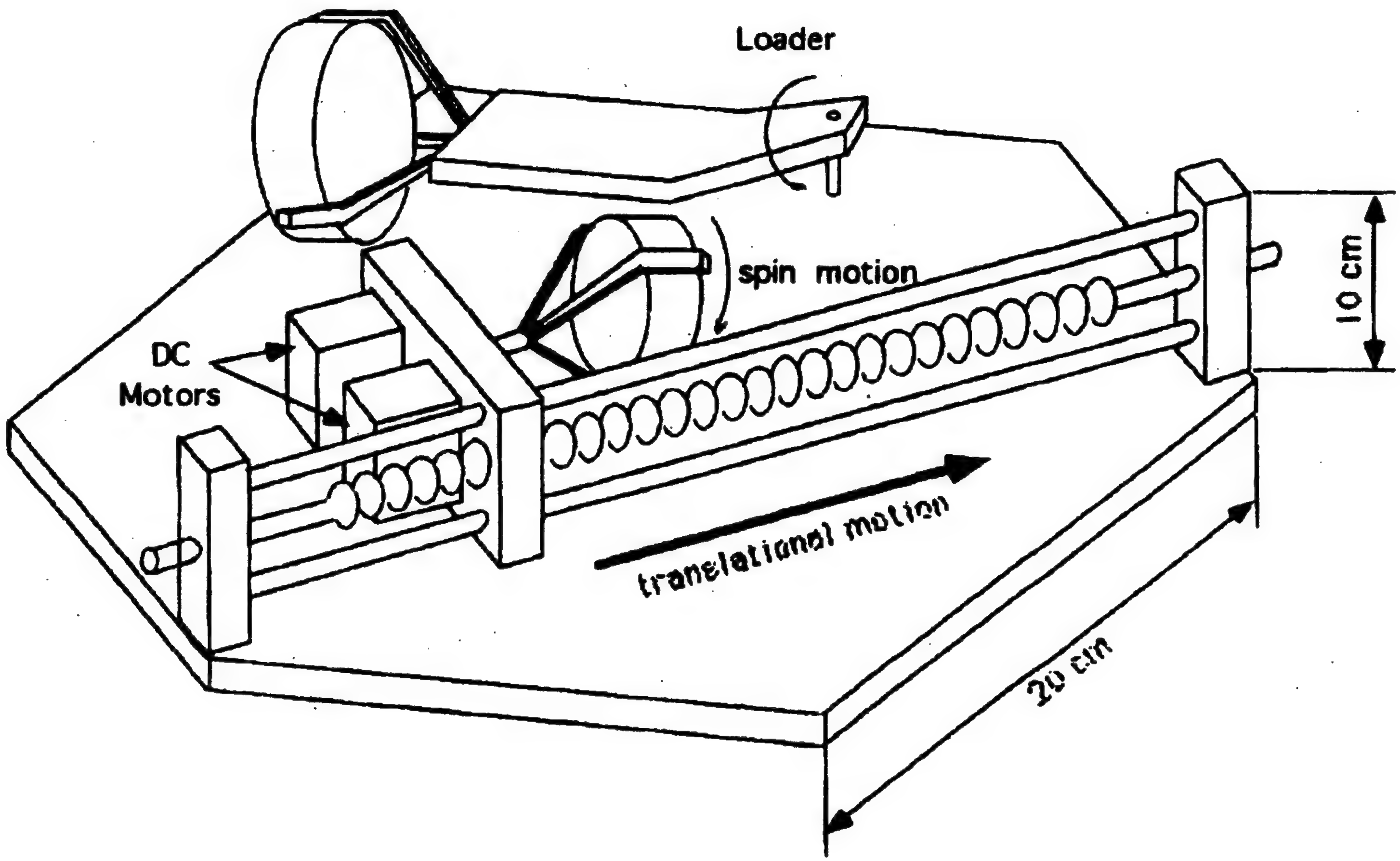
FFM Launcher Design

(Jason Suchman)
Stanford University



Heritage:
Orbiting Pico-SAT Automatic Launcher (OPAL)
platform in
Stanford's Satellite QUIck Reaction Testbed (SQUIRT)

H. Javadi 8/15/95

Figure C-1. OPAL Stanford University Launcher

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APPENDIX D

SPREADSHEET ANALYSIS

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DIRECT DRIVE, FACE-ON FFM LAUNCH DESIGN			
DRIVE WHL. SIZING & LAUNCHER PERFORMANCE:			
(@ max. ffm vel.=10 m/s, & @ max. ffm spin=1200 rpm, & @ max. ffm size; no slip assumed			
between drive wheels & ffm; drive wheels and ffm are assumed to be in constant contact.)			
	INPUT	**INPUT**	**INPUT**
Launcher Config. #	*Req'd. FFM Spin (rpm)*	*Req'd. FFM Lin. Vel.(m/s)*	*FFM diameter (m)*
(note: 1 launcher only)	(at FFM ejection)	(at FFM ejection)	
		V	
1	1200	10	0.07
2	1200	10	0.07
3	1200	10	0.07
4	1200	10	0.07
5	1200	10	0.07
6	1200	10	0.07
7	1200	10	0.07
8	1200	10	0.07
9	1200	10	0.07
10	1200	10	0.07
DRIVE WHEEL SPEED/ANGLE STUDY:			
(drive wheel dia. = 11" constant)			
	INPUT	**INPUT**	**INPUT**
Launcher Config. #	*Req'd. FFM Spin (rpm)*	*Req'd. FFM Lin. Vel.(m/s)*	*FFM diameter (m)*
(note: 1 launcher only)	(at FFM ejection)	(at FFM ejection)	
1	1200	10	0.07
2	1000	9	0.07
3	950	8	0.07
4	900	7	0.07
5	850	6	0.07
6	800	5	0.07
7	750	4	0.07
8	700	3	0.07
9	650	2	0.07
10	600	1	0.07
DRIVE WHEEL SPEED/ANGLE STUDY:			
(drive wheel dia. = 8.27" constant)			
	INPUT	**INPUT**	**INPUT**
Launcher Config. #	*Req'd. FFM Spin (rpm)*	*Req'd. FFM Lin. Vel.(m/s)*	*FFM diameter (m)*
(note: 1 launcher only)	(at FFM ejection)	(at FFM ejection)	
1	1200	10	0.07
2	1000	9	0.07
3	950	8	0.07
4	900	7	0.07
5	850	6	0.07
6	800	5	0.07
7	750	4	0.07
8	700	3	0.07
9	650	2	0.07
10	600	1	0.07

INPUT	**INPUT**	**INPUT**	**INPUT**
FFM height (m)	*FFM Inertia (kg-sq. m)*	*FFM mass (grams)*	*Drive Wheel diameter (m)*
			(assume: two identical drive wheels
			w/ one direct-drive motor per wheel)
		m	
0.02	5.82E-05	1.00E+02	0.04
0.02	5.82E-05	1.00E+02	0.07
0.02	5.82E-05	1.00E+02	0.14
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.35
0.02	5.82E-05	1.00E+02	0.42
0.02	5.82E-05	1.00E+02	0.49
0.02	5.82E-05	1.00E+02	0.56
0.02	5.82E-05	1.00E+02	0.63
INPUT	**INPUT**	**INPUT**	**INPUT**
FFM height (m)	*FFM Inertia (kg-sq. m)*	*FFM mass (grams)*	*Drive Wheel diameter (m)*
			(assume: two identical drive wheels
			w/ one direct-drive motor per wheel)
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
0.02	5.82E-05	1.00E+02	0.28
INPUT	**INPUT**	**INPUT**	**INPUT**
FFM height (m)	*FFM Inertia (kg-sq. m)*	*FFM mass (grams)*	*Drive Wheel diameter (m)*
			(assume: two identical drive wheels
			w/ one direct-drive motor per wheel)
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21
0.02	5.82E-05	1.00E+02	0.21

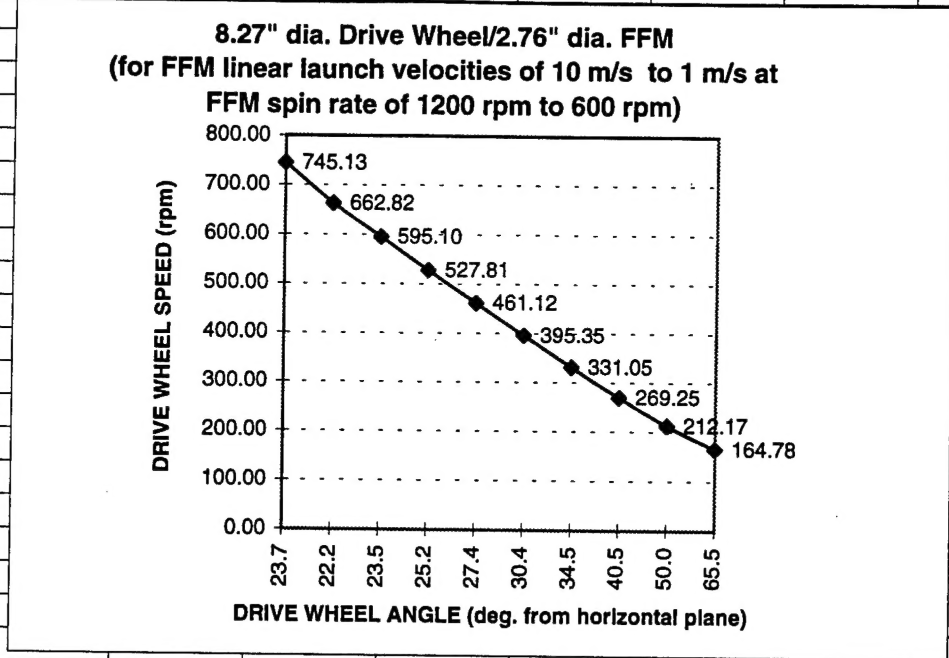
INPUT	**INPUT**	**INPUT**
Drive Wheel height (m)	*Drive Wheel Inertia (kg-sq. m)*	*Required Re-Launch Time*
	(per wheel, estimated)	(sec., assumed)
		TL
0.02	5.82E-05	5.00E+00
0.02	1.02E-04	5.00E+00
0.02	2.04E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	5.09E-04	5.00E+00
0.02	6.11E-04	5.00E+00
0.02	7.13E-04	5.00E+00
0.02	8.15E-04	5.00E+00
0.02	9.17E-04	5.00E+00
INPUT	**INPUT**	**INPUT**
Drive Wheel height (m)	*Drive Wheel Inertia (kg-sq. m)*	*Required Re-Launch Time*
	(per wheel)	(sec.)
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
0.02	4.07E-04	5.00E+00
INPUT	**INPUT**	**INPUT**
Drive Wheel height (m)	*Drive Wheel Inertia (kg-sq. m)*	*Required Re-Launch Time*
	(per wheel)	(sec.)
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00
0.02	3.06E-04	5.00E+00

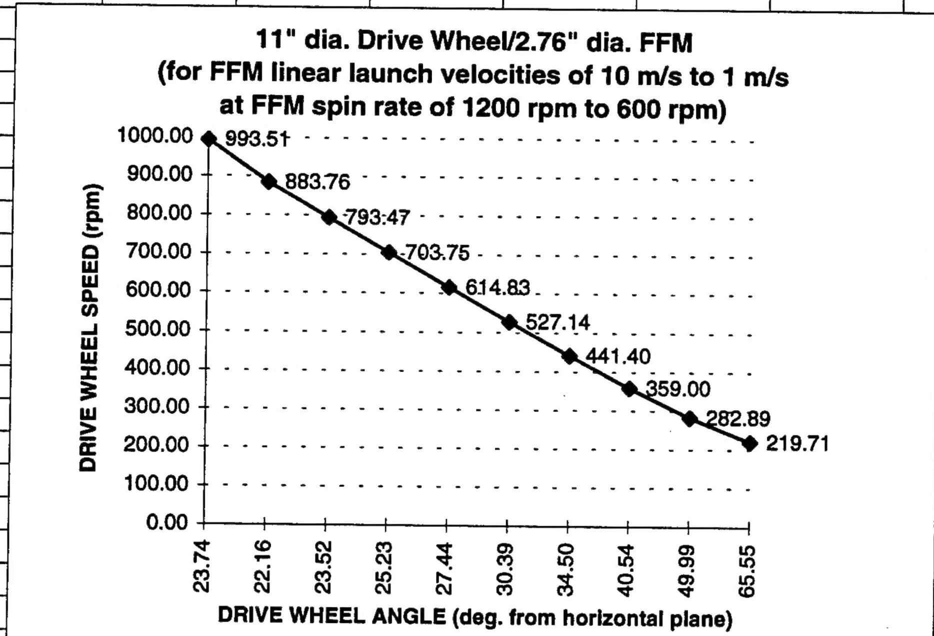
INPUT	**INPUT**	**OUTPUT**
Typ. Satellite Payload Mass (kg)	*Typ. Spacecraft Orbit Altitude (nm)*	***Req'd. Drive Wheel Angle from Horizontal Plane (deg.)***
MP		Beta
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	23.74
INPUT	**INPUT**	**OUTPUT**
Satellite Payload Mass (kg)	*Spacecraft Orbit Altitude (nm)*	***Req'd. Drive Wheel Angle from Horizontal Plane (deg.)***
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	22.16
1.55E+02	2.00E+02	23.52
1.55E+02	2.00E+02	25.23
1.55E+02	2.00E+02	27.44
1.55E+02	2.00E+02	30.39
1.55E+02	2.00E+02	34.50
1.55E+02	2.00E+02	40.54
1.55E+02	2.00E+02	49.99
1.55E+02	2.00E+02	65.55
INPUT	**INPUT**	**OUTPUT**
Satellite Payload Mass (kg)	*Spacecraft Orbit Altitude (nm)*	***Req'd. Drive Wheel Angle from Horizontal Plane (deg.)***
1.55E+02	2.00E+02	23.74
1.55E+02	2.00E+02	22.16
1.55E+02	2.00E+02	23.52
1.55E+02	2.00E+02	25.23
1.55E+02	2.00E+02	27.44
1.55E+02	2.00E+02	30.39
1.55E+02	2.00E+02	34.50
1.55E+02	2.00E+02	40.54
1.55E+02	2.00E+02	49.99
1.55E+02	2.00E+02	65.55

OUTPUT	**OUTPUT**
Req'd. Drive Wheel Speed (rpm)	***Instantaneous I/O Torque per Motor (oz.-in.)***
	(at req'd. FFM spin rate)
w	T
5215.92	1309.87
2980.53	783.12
1490.26	431.96
993.51	314.90
745.13	256.37
596.11	221.26
496.75	197.85
425.79	181.12
372.57	168.58
331.17	158.83
OUTPUT	**OUTPUT**
Req'd. Drive Wheel Speed (rpm)	***Instantaneous I/O Torque per Motor (oz.-in.)***
	(at req'd. FFM spin rate)
745.13	256.20
662.82	198.69
595.10	162.97
527.81	130.93
461.12	102.59
395.35	77.96
331.05	57.06
269.25	39.93
212.17	26.68
164.78	17.51
OUTPUT	**OUTPUT**
Req'd. Drive Wheel Speed (rpm)	***Instantaneous I/O Torque per Motor (oz.-in.)***
	(at req'd. FFM spin rate)
993.51	315.25
883.76	245.41
793.47	200.63
703.75	160.56
614.83	125.21
527.14	94.58
441.40	68.71
359.00	47.64
282.89	31.47
219.71	20.40

OUTPUT	**OUTPUT**
Max. Current Usage (Amps)	***Max. Power Useage (Watts)***
(@28 VDC; motor eff.=0.75)	
a = [T x 2 x pi x w x 246]/[33,000 x 28v x eff.]	W = (T x w) x 2
240.68	10108.61
82.23	3453.46
22.68	952.44
11.02	462.89
6.73	282.64
4.65	195.14
3.46	145.41
2.72	114.10
2.21	92.93
1.85	77.82
OUTPUT	**OUTPUT**
Max. Current Usage (Amps)	***Max. Power Useage (Watts)***
(@28 VDC; motor eff.=0.75)	
6.73	282.45
4.64	194.85
3.42	143.49
2.43	102.25
1.67	70.00
1.09	45.60
0.67	27.95
0.38	15.91
0.20	8.38
0.10	4.27
OUTPUT	**OUTPUT**
Max. Current Usage (Amps)	***Max. Power Useage (Watts)***
(@28 VDC; motor eff.=0.75)	
11.03	463.40
7.64	320.89
5.61	235.54
3.98	167.18
2.71	113.90
1.76	73.77
1.07	44.87
0.60	25.31
0.31	13.17
0.16	6.63

OUTPUT	OUTPUT			
Total Power Useage per	***Impulse Force on Spacecraft***			
FFM launch (Watt-hr)	***from a single FFM launch (lbs.)***			
	(impulse duration of .25 sec.)			
P = TL x W	F =[[MP x (m x v/MP)] / .25s]/4.45			
14.04	0.899			
4.80	0.899			
1.32	0.899			
0.64	0.899			
0.39	0.899			
0.27	0.899			
0.20	0.899			
0.16	0.899			
0.13	0.899			
0.11	0.899			
OUTPUT	OUTPUT			
Total Power Useage per	***Impulse Force on Spacecraft***			
FFM launch (Watt-hr)	***from a single FFM launch (lbs.)***			
	(impulse duration of .25 sec.)			
0.39	0.899			
0.27	0.809			
0.20	0.719			
0.14	0.629			
0.10	0.539			
0.06	0.449			
0.04	0.360			
0.02	0.270			
0.01	0.180			
0.01	0.090			
OUTPUT	OUTPUT			
Total Power Useage per	***Impulse Force on Spacecraft***			
FFM launch (Watt-hr)	***from a single FFM launch (lbs.)***			
	(impulse duration of .25 sec.)			
0.64	0.899			
0.45	0.809			
0.33	0.719			
0.23	0.629			
0.16	0.539			
0.10	0.449			
0.06	0.360			
0.04	0.270			
0.02	0.180			
0.01	0.090			


8.27" dia. Drive Wheel/2.76" dia. FFM
(for FFM linear launch velocities of 10 m/s to 1 m/s at
FFM spin rate of 1200 rpm to 600 rpm)
DRIVE WHEEL SPEED (rpm)
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
745.13
662.82
595.10
527.81
461.12
395.35
331.05
269.25
212.17
164.78
23.7
22.2
23.5
25.2
27.4
30.4
34.5
40.5
50.0
65.5
DRIVE WHEEL ANGLE (deg. from horizontal plane)


11" dia. Drive Wheel/2.76" dia. FFM
(for FFM linear launch velocities of 10 m/s to 1 m/s
at FFM spin rate of 1200 rpm to 600 rpm)
DRIVE WHEEL SPEED (rpm)
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
993.51
883.76
793.47
703.75
614.83
527.14
441.40
359.00
282.89
219.71
23.74
22.16
23.52
25.23
27.44
30.39
34.50
40.54
49.99
65.55
DRIVE WHEEL ANGLE (deg. from horizontal plane)

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Condon, J.A.; Hollis, M.S.L.; Brandon, F.J.

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13. ABSTRACT *(Maximum 200 words)*

The need exists for a launch mechanism to propel a magnetometer (i.e., free-flying magnetometer [FFM]) from a high altitude sounding rocket or low earth-orbiting (LEO) satellite. Research has been conducted to conceptually design a unique launcher for this purpose. This launcher will provide the greatest degree of variability in FFM launch velocity and spin rate, according to the given requirements, and will allow for two distinct FFM spatial geometric launching orientations with respect to the major launch axis. Also, this launcher will be relatively easily integrated into existing or future space or rocket host vehicles.

14. SUBJECT TERMS

drive wheel	face on	satellite
edge on	prototype	sounding rocket

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